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Quantitative characteristics of quality of the active-pulse television systems

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***Abstract*— The quantitative characteristics of quality assessment in the active-pulsed television system, taking into account the loss in agreeing an optoelectronic transducer and a television transmitter, are consider.**

***Keywords*— television images; sensitivity; electron-optical converter; charge-coupled device**

I. Introduction

This paper is an extension of work originally presented in 2016 at the IEEE International Conference on Dynamics of Systems, Mechanisms and Machines (Dynamics) [1].

Currently, for the detection, monitoring and measurement of objects parameters in different environmental conditions apply active-pulsed television systems (APTVS). Their operating principle is based on the pulse method of the system view field illumination and the laser emitters gating time pulses reflected from the object of observation [2].

In the active-pulsed mode operation of the system observed object is illuminated with laser light pulses. In synchronization with the strobe illumination pulses are carried out and receiving radiation reflected from the object signal electron-optical converter (EOC), equipped with a quick-release fastener, opening in time with the sending pulses.

The principle of an impulse method in itself of observation is known for a long time (it is offered by the academician A.A. Lebedev in 1936), a large number of scientific operations on active and impulse to observation instruments is published. Now the active development samples active and impulse instruments, as at us in the country, and abroad are observed. As for, methods of processing of the images received from such instruments, they are mentioned in literature extremely seldom. As a rule, vendors of active and impulse instruments are restricted to an opportunity to add the received image some information on depth of the fissile region of vision and a time delay of time gating that approximately allows to define a distance to object of observation with a margin error to an equal half of vision the fissile region depth. (5 – 10 meters).

For assessment sensitivity APTVS must know sensitivity a solid state photoelectric converter (PEC). Although on difference approaches, most authors isolated exactly sensitivity as one of major characteristics.

The image of a field of vision of APTVS created by an input lens on a photocathode an electron-image tube after conversion and gain of brightness is transferred through a coordinating lens from the electron-image tube screen to light-sensitive array elements of the charge coupled device of the video camera, processed by the hardware and software and displayed on the monitor of the operator. The video information received as a result of processing by television and computing means is used for observation, measurement, monitoring and registration of the informative parameters of objects. For assessment of APTVS sensitivity is necessary to know sensitivity of the solid-state photo-electric transformer.

Existence of the advancing or delaying sublight signals from non-uniformity on the route of observation leads to appearance of additional video images both reflected signals, and in addition highlit objects which are absent in reference conditions of observation. It needs to be considered in case of assessment of characteristics of system.

Sensitivity usually determined by as value illumination on facility at suites, providing specified options quality output video. In this must be contains color temperature source light-temperature thread incandescent at degrees Kelvin, for example, most typical light sources type "A" have color temperature T = 2854 K or the same halogen lamp from T = 3200 K. However, characteristic spectral sensitivity matrix CCD significantly is different from crooked visibility visual analyzer. In many works, the sensitivity is seen mostly qualitative, there are no strict definitions and conclusions of the relevant statements, there are no examples of calculation for specific matrix CCD and APTVS based on them.

II. Problem Definition

At the conference [1], the methods for estimating the integral and spectral sensitivity of APTVS were presented and the following tasks were solved:

1. Clarified formula for definitions the optical gain in brightness, taking into account losses in coordination EOC and television sensor.

$$k_B = \frac{2\pi\tau_o}{\beta^2}\left[1 - \frac{1}{\sqrt{1+d^2}}\right],$$

$$d = \frac{D_{inp}\beta}{2f_o(1+\beta)},$$

$\beta = \frac{a'}{a}$ – module matching the magnification optics (linear scale image);

τ_o – transmittance lens matching;

D_{inp} – the diameter of the input matching ens, m;

f – lens focal length matching system, m.

2. Received formula for definitions illumination of the photosensitive surface of the matrix for assessments integral sensitivity APTVS.

$$E_{CCD} = B_o k_B = B_o \frac{2\pi\tau_o}{\beta^2}\left[1 - \frac{1}{\sqrt{1+d^2}}\right],$$

E_{CCD} – illumination of the photosensitive surface of the CCD sensor;

B_o – the object brightness.

3. Received the analytical expressions of the relative spectral sensitivity of the eye to simplify preliminary calculations

$$V_d(\lambda) = \exp\left[-\left(\frac{\lambda - 0{,}559}{0{,}060283}\right)^2\right],$$

$$V_n(\lambda) = \exp\left[-\left(\frac{\lambda - 0{,}5025}{0{,}05475}\right)^2\right],$$

$V(\lambda)$ – relative spectral response of the electronic flow of radiation of the radiation source.

III. THEORY

The technical documentation, as a rule, gives data on the integral sensitivity of the radiation receiver to the light flux and the spectral sensitivity characteristics in relative units.

To determine the quantum yield of the photocathode η_{PEC} at a wavelength λ_1 is necessary to know its sensitivity at this wavelength. If the wavelength is expressed in nanometers and the sensitivity $S_{\lambda 1}$ is expressed in mA / W, the quantum yield will be equal to

$$\eta_{PEC} = \frac{S_{\lambda 1}}{0.807\lambda_1} \qquad (1)$$

Communication between the absolute value of the sensitivity at the wavelength λ_1 ($S_{\lambda 1}$)) and the integral light sensitivity (S^l) and the relative spectral sensitivity characteristic ($s(\lambda_1)$)) is set by the relation [3]

$$S_{\lambda 1} = 683 S^l \frac{k_e}{k_s} S(\lambda_1) \qquad (2)$$

k_e, k_s - coefficients using the eyes and the radiation detector to a reference source such as "A", for example.

If the coefficients of use in (2) are determined from the same source of radiation, then the ratio of the coefficients can be written in the form

$$\frac{k_e}{k_s} = \frac{\int y(\lambda) V(\lambda)\, d\lambda}{\int y(\lambda) s(\lambda)\, d\lambda} \qquad (3)$$

$V(\lambda)$ - curve visibility eye;

$s(\lambda)$ - relative spectral sensitivity characteristic of the image intensifier photocathode;

$y(\lambda)$ - relative spectral radiation flux characteristic.

For an absolutely black body, the relative spectral characteristic of the radiation flux is described by Planck's law

$$y(\lambda) = 142.3\left(\frac{\lambda}{\lambda_{max}}\right)^{-5}\left\{\exp\left[\frac{4.965\lambda_{max}}{\lambda}\right] - 1\right\}^{-1} \qquad (4)$$

Taking into consideration that the color temperature of the source type "A" is equal to 2856 K, we compute the value λ_{max}

$$\lambda_{max} = 2898 \cdot 10^3 / T = 1014.7 nm.$$

Using the results of the approximation of the eye curve, the characteristic of the relative spectral sensitivity of the photocathode and the analytical dependence (4), we can determine the ratio of use coefficients (3).

Substituting the obtained values of k_e/k_s., the integral light sensitivity and a relative spectral sensitivity at a wavelength of λ_1, we obtain the absolute value of the sensitivity at that wavelength, expressed in mA / W.

Knowing the absolute value of the sensitivity at the wavelength λ_1, from (1) can determine the quantum yield of the photocathode at a wavelength of λ_1.

Integral sensitivity is the ratio of the output video signal to the illumination on the photosensitive surface or object under the given conditions – the accumulation of time, the color temperature of the light source, etc. Referring to the concept of illumination on light-sensitive surface.

The illumination on the light-sensitive light-signal converter layer, in general, consists of two parts, one of which is created by the light forming the optical image and the other by the scattered light.

The scattering of light is due to impurity particles inside the glass itself, dust and moisture on the surfaces of the lenses, reflections from the glass-air interface and the inner elements of the lens and the TV camera [4].

Reflected from the glass-air interface, the beams create secondary images that are light spots in the image plane. And since the spots overlap, the parasitic illumination they create is almost uniform. Parasitic illumination is superimposed on the primary optical image, thereby reducing the image contrast.

Taking into account [1, 4], the total illumination of the image on the photosensitive surface of the TV sensor will be

$$E = (1-\eta_p)E_{ob}\frac{\rho\tau}{\beta^2}2\left[1-\frac{1}{\sqrt{1+d^2}}\right]+\eta_p E_m \quad (5)$$

For the case of a uniform distribution of scattered light, the light scattering coefficient can be represented in the form [4]

$$\eta_p = r^2\left\{1+\frac{1}{1-\tau_1^2}\left[2(N_{n.p}-1)-\frac{\tau_1^{4(N_{n.p}-1)}}{1-\tau_1^2}\right]\right\},$$

$$\tau_1 = \frac{4n}{(n+1)^2};$$

n - index of refraction of the glass;

$r = \frac{(n-1)^2}{(n+1)^2}$ - the Fresnel reflection coefficient.;

$N_{n.p}$- number of "glass - air" interfaces;

E_m - mean illumination TV photosensitive sensor surface.

It follows from (5) that in the absence of scattering the dependence of the illumination on the brightness of the object is linear. In the presence of scattering, the radiation energy is redistributed between the image sections. The drop in illumination in the light areas of the image is accompanied by an increase in the dark areas.

The magnitude of the illumination of the image area depends on the distribution of brightness on the object, the distance from the center of the lens, the maximum brightness and contrast of the scene, i.e., the amount of illumination due to scattered light for different points of the image plane should have different values. From this it follows that if one approaches the treatment of phenomena in the optical system rigorously, each characteristic point of the projection plane will have its own transmission characteristic, determined by (5).

The spectral sensitivity characteristics of solar cells is defined as the dependence of the accumulated and transmitted to the output photogenerated charge packet of the wavelength λ.

Using (5), generally an expression for determining the number of photoelectrons registered potential pit pixel CCD

$$n_c == (1-\eta_p)\frac{2\pi\eta(\lambda)\lambda t B_v \tau_o A_e}{683k\beta^2 h c}\left[1-\frac{1}{\sqrt{1+d^2}}\right]+\eta_p E_m$$

t – time of accumulation;

A_e – element area;

$\eta(\lambda)$ – the quantum efficiency of the matrix;

h – Planck's constant;

c – the speed of light;

$\beta = \frac{a'}{a}$ – module matching the magnification optics (linear scale image);

τ_o – transmittance lens matching;

$$d = \frac{D_{inp}\beta}{2f(1+\beta)};$$

$$k = \frac{\int_0^\infty y(\lambda)V(\lambda)d\lambda}{\int_0^\infty y(\lambda)d\lambda};$$

B_v – the brightness of the image intensifier;

D_{inp} – the diameter of the input matching lens;

f – lens focal length matching system.

IV. DISCUSSION OF RESULTS

After calibrating the APTVS and checking the object recognition, experimental tests of the system were carried out.

In fig. 1 shows the original image (before processing) when the system is adjusted to a viewing range of 30 m. Fig. 2 shows the image after processing by the filter of the interframe difference with the subsequent correction of the brightness range of the image. Thus, as a result of the experiment, the source of parasitic radiation (glowing windows of the building) was "eliminated" with the help of a developed and implemented interframe difference filter.

Fig. 1. Image before processing (range 30 m)

Fig. 2. Processing result (range 30 m)

V. CONCLUSION

Component heads identify the different components of your as a result of this work the following results were obtained:

1. Refined the formula for determining the quantum yield of the PEC photocathode.
2. Received formula for determining total illumination to evaluate the integral sensitivity APTVS.
3. Received formula for determining number of photoelectrons in the potential well for the pixel for evaluating spectral sensitivity APTVS.

VI. ACKNOWLEDGMENT

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